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4.7: Human Factors Design Criteria for Liquid Crystal Displays

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Introduction

Liquid crystal display (LCD) technology offers several potential advantages over CRT display media, especially as applied to the airborne environment. CRT characteristics of size, weight, power requirements and fragility have been of concern to designers incorporating them into present and proposed aircraft cockpits. In addition, in high ambient brightness environments, CRT imagery may appear "washed out" due to light reflection from the CRT faceplate and phosphor. By comparison, the LCD offers a display media with significant power and form factor savings in addition to an inherent capacity to reflect incident light so that high ambient luminance conditions increase display brightness without causing a loss of contrast.

An excellent discussion of the physical properties and characteristics of LCD's may be found in Lechner, et al (1) as well as in the more recent review by Goodman (2).

In order that LCD devices be applied most effectively as candidate replacements for CRT's, several human factors issues need to be addressed. Specifically, the percent active area and required element density have been identified as areas of greatest concern. Percent active area is computed as the ratio of the area of the display containing the liquid crystal material to the total area of the display, times 100. The dead area, or non-active portion of each display element, corresponds to the area required for the element driving electronics. Liquid crystal displays currently being produced have a percent active area of approximately 93 percent with packing densities of 100 elements per inch. If the element density is increased, the percent active area would decrease proportionately, since the amount of dead area per element must remain approximately the same for a given design of the driving electronics.

The dead area forms a grid pattern across the face of the display, and this, together with the effect of element density, may result in a limitation on the performance levels of human operators in target detection, recognition or identification tasks.

However, specific levels of percent active area and element density may be achieved, beyond which no additional improvement in operator performance could be expected. If the number of resolution elements across the target exceeds the resolution capability of the human visual system, the operator, not the display, becomes the limiting factor in the visual task. If the number of elements across the target is less than the resolution capability of the visual system, the display becomes the limiting factor. Figure 1 depicts these relationships for an arbitrary target recognition task.

Method

Element density (i.e., in terms of the visual angle subtended by individual display resolution elements) was experimentally manipulated by adjusting the subjects' viewing distance from a rear projection screen on which a grid mask was placed. The grid masks provided percent active area levels of 55, 69, 81, and 100 (i.e., no mask) percent. The military, tactical type targets used were presented in a zoom fashion at a simulated slant range which initially precluded recognition. As the target size increased, subjects were asked to press a remote projector control button when they were "virtually certain" of their responses. This instructional set produced a correct response rate of approximately 96 percent.

Results

Figure 2 shows the lack of effect of percent active area (i.e., down to 55 percent) on target recognition performance for element angular subtense values between 0.75 and 3.0 minutes of arc (corresponding to element densities of from approximately 165 to 40 elements per inch at a 28 inch viewing distance). As shown in both Figures 2 and 3, the effects of element angular subtense were large and were determined to be statistically reliable ($F = 27.5$, $P < .001$). These results also conformed to expectations derived from the limiting resolution of the visual system.

Figures 1 and 3 provide a comparison of the theoretical and empirical relationships, respectively, between subtended angle across individual display resolution elements and subtended angle across a target at time of recognition. The differences between the ordinate values of pilot study and main study data in Figure 2 reflect slight differences in the response criterion employed by the two sets of subjects. That is, a prior phase of the pilot study involved

manipulation of instructional set, which later resulted in a slightly different response bias, relative to main study subjects.

Conclusion

It is apparent from the data of Figure 3 that the angular subtense per element need not be less than approximately 1.3 minutes of arc to provide adequate display resolution.

Figure 4 shows the derived relations between viewing distance and element density at three assumed values of the "break" point between the visual system limited situation and the display limited case. It may be seen in Figure 4 that at a viewing distance of 28 inches the 1.3 value corresponds very nearly to the 100 elements per inch packing density of state-of-the-art liquid crystal display devices. The 93 percent level of active area of presently produced LCD's is not expected to have an adverse effect on operator performance.

References

1. B. J. Lechner, F. J. Marlow, E. O. Nester, and J. Tults, "Liquid Crystal Matrix Displays," Proc. IEEE, Vol. 59, pp. 1566-1579, 1971.

2. L. A. Goodman, "The Relative Merits of LED's and LCD's," Vol. 16, pp. 8-19, 1975.

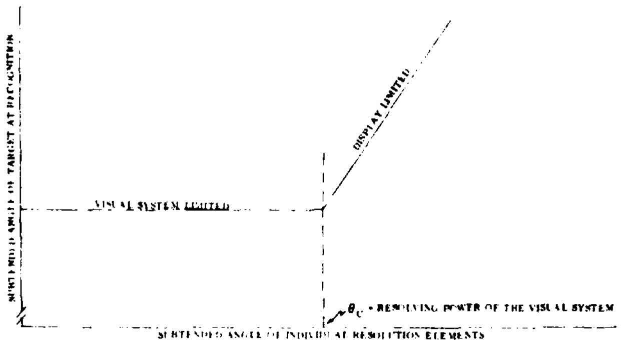

FIGURE 1. SUBTENDED ANGLE OF TARGET FOR A GIVEN PROBABILITY OF RECOGNITION AS IT THEORETICALLY WOULD BE INFLUENCED BY SUBTENDED ANGLE OF INDIVIDUAL RESOLUTION ELEMENTS IN THE DISPLAY.

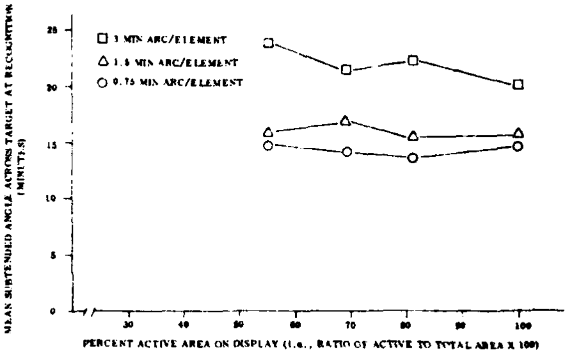

FIGURE 2. EFFECT OF GRID CONDITION ON TARGET RECOGNITION AT THREE ELEMENT ANGULAR SUBTENSE VALUES - MAIN STUDY

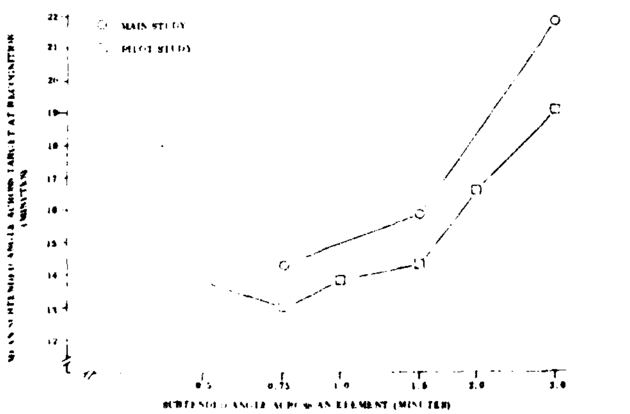

FIGURE 3. COMPARISON OF TARGET RECOGNITION DATA - PILOT STUDY VERSUS MAIN STUDY

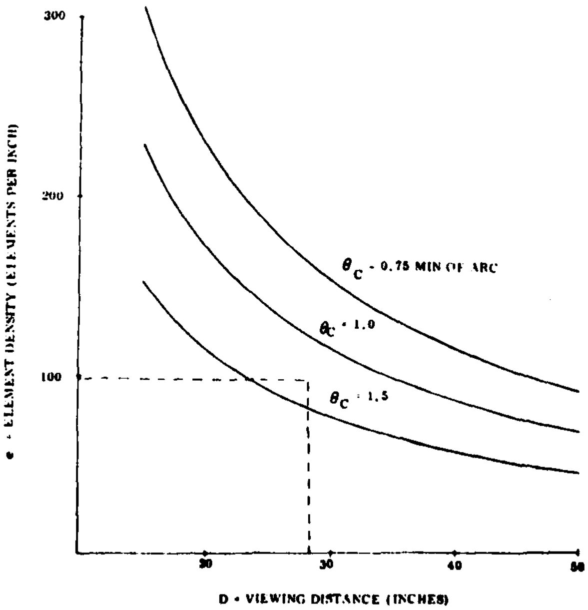

FIGURE 4. REQUIRED ELEMENT DENSITY VS VIEWING DISTANCE FOR THREE VALUES OF EYE RESOLUTION CAPABILITY